to a subsequent ion stage or instrument. The IFT serves as an interface between at least two ion stages, which stages are not limited. Stages include, but are not limited to, e.g., ion mobility spectrometry (IMS) stages, field asymmetric waveform ion mobility spectrometry (FAIMS) stages, longitudinal electric field-driven FAIMS stages, ion mobility spectrometry with alignment of dipole direction (IMS-ADD), higher-order differential ion mobility spectrometry (HODIMS) stages, parallel planar and non-parallel planar stages, and including components thereof. A preferred ion analysis stage is a time-of-flight mass spectrometer (TOF-MS), e.g., an orthogonal acceleration TOF-MS (i.e., oa-TOF-MS). With high analysis speed, high sensitivity, high mass resolving power, and high mass accuracy, oa-TOF-MS represents an attractive platform for proteomics. The ion trap can be coupled to an oa-TOF-MS, e.g., to increase the instrument duty cycle for operation, e.g., with continuous ion sources such as ESI. Here, an electrospray ionization source provides ions to the ion funnel. Other ion sources can be employed that include, but are not limited to, e.g., MALDI, and other ion sources. The ion trap can employ pressures of from about 10^{-3} Torr to about 5 Torr. Since trapping efficiency is proportional to the collision gas pressure, increasing pressure can offer greater sensitivity. In a preferred configuration, the ion trap couples to, or is integrated with, an electrodynamic ion funnel which provides efficient transmission of ions to the IFT. The ion trap provides preselected dc-potentials and rf-potentials that are independent of any dc-potentials and rf-potentials delivered by, e.g., a coupled ion funnel. In addition, the ion trap can provide a dc-gradient that is controlled independently from a dc-gradient of the ion funnel. The dc-gradients of the ion trap are not limited. In an exemplary configuration, the dc-gradient of the ion trap is between about 1 V/cm and about 5 V/cm; the dc-gradient of the ion funnel is between about 10 V/cm and about 30 V/cm. In this configuration, the ion trap includes an rf-frequency of about 600 kHz, an amplitude of about 55 V_{p-p}, and a pressure of about 1 Torr and 5 Torr, which parameters are not limited. The ion trap operates at a typical pressure in the range from about 1 Torr to about 10 Torr. A coupled ion funnel may be operated in tandem, e.g., at a pressure selected in the range from about 0.1 Torr to about 100 Torr. The ion trap operates at typical temperatures in the range from about 25° C. to about 50° C. Gas flows inside the ion trap collection portion are nominal. The ion trap can have a length in the range from about 0.5 mm to about 50 mm. The ion trap can also have an inner electrode geometry cross section in the range from about 0.02 mm to about 20 mm. Control over dc-field distribution in the ion trap is crucial for fast ion ejection.

[0005] The invention is also a method for transmission of ions between at least two operatively coupled instrument stages for ion analysis that includes the steps of: introducing ions in an ion beam from an ion source to an ion trap that includes: an inlet portion that diverges the ions in the ion beam introduced thereto to expand same; a trapping portion that is operatively coupled to the inlet portion that traps ions received from the inlet portion in the ion beam and accumulates the same therein; the trapping portion includes an entrance grid that is coupled at a receiving end thereof that controls entry of the ions from the inlet portion into the trapping portion; the trapping portion includes an exit grid that is coupled to a releasing end thereof that controls outflow of ions therefrom; and an outlet portion that is coupled to the trapping portion that converges ions released from the trapping portion to converge and focus the same; trapping a preselected quantity of the ions in the trapping portion for a preselected time to accumulate same; and selecting at least one of the ions that is accumulated in the trapping portion; and releasing at least one of the ions at a preselected pressure for analysis of same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1***a* is a schematic of an ion funnel trap (IFT), according to an embodiment of the invention.

[0007] FIG. **1***b* is a schematic of the IFT coupled with an electrodynamic ion funnel, according to a preferred embodiment of the invention.

[0008] FIG. **2** is a lengthwise cross-sectional view of the ion funnel trap (IFT) coupled with an electrodynamic ion funnel.

[0009] FIGS. **3***a*-**3***f* illustrate various inner geometries of electrodes of the ion trap.

[0010] FIG. **4** is a schematic that shows components for delivering waveforms used in conjunction with the ion funnel trap.

[0011] FIG. **5** illustrates an exemplary instrument system that employs the ion funnel trap of the invention.

[0012] FIG. **6** presents a voltage profile for operation of the ion funnel trap.

[0013] FIG. **7** presents a timing sequence for operation of the ion funnel trap.

[0014] FIG. **8** is a plot showing current pulse measurements for a solution comprising 1 μM Reserpine analyzed in conjunction with the ion funnel trap, according to an embodiment of the method of the invention.

[0015] FIG. **9** is a plot showing the trap capacity and efficiency of the ion trap.

[0016] FIG. **10** is a mass spectrum of a simple peptide mixture processed in trapping and continuous modes in a TOF-MS, according to an embodiment of the method of the invention.

[0017] FIGS. **11***a*-**11***b* are plots showing signal intensities for two exemplary peptides as a function of accumulation time processed in trapping and continuous modes at different analyte concentrations.

DETAILED DESCRIPTION

[0018] The present invention is an ion funnel ion trap (IFT) and process. In a preferred configuration, the ion trap is coupled to an electrodynamic ion funnel, which ion funnel is detailed, e.g., by Shaffer et al. in (*Rapid Commun. Mass Spectrom.* 1997, 11, 1813-1817), incorporated herein in its entirety. Coupling the ion trap with an electrodynamic ion funnel provides the ability to accumulate, store, and eject ions, e.g., in conjunction with various ion analysis instruments including, but not limited to, e.g., ion mobility spectrometry (IMS) instruments, time-of-flight mass spectrometry (TOF-MS) instruments, IMS/TOF-MS instruments, and other instruments and configurations. For example, when coupled to an ion mobility spectrometry (IMS) instrument, the IFT elevates charge density of ion packets ejected from the ion funnel trap (IFT) and provides a considerable increase in overall ion utilization efficiency to the IMS instrument. Coupling to an electrodynamic ion funnel trap improves sensitivity of commercial TOF-MS instruments and can potentially be coupled to other TOF-MS instrument systems available commercially. In addition, the ion funnel trap is expected